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STRUCTURAL RELATIONS OF THE PRE-CAMBRIAN AND PALÆOZOIC ROCKS NORTH OF THE OTTAWA AND ST. LAWRENCE VALLEYS

by

E. M. Kindle and L. D. Burling

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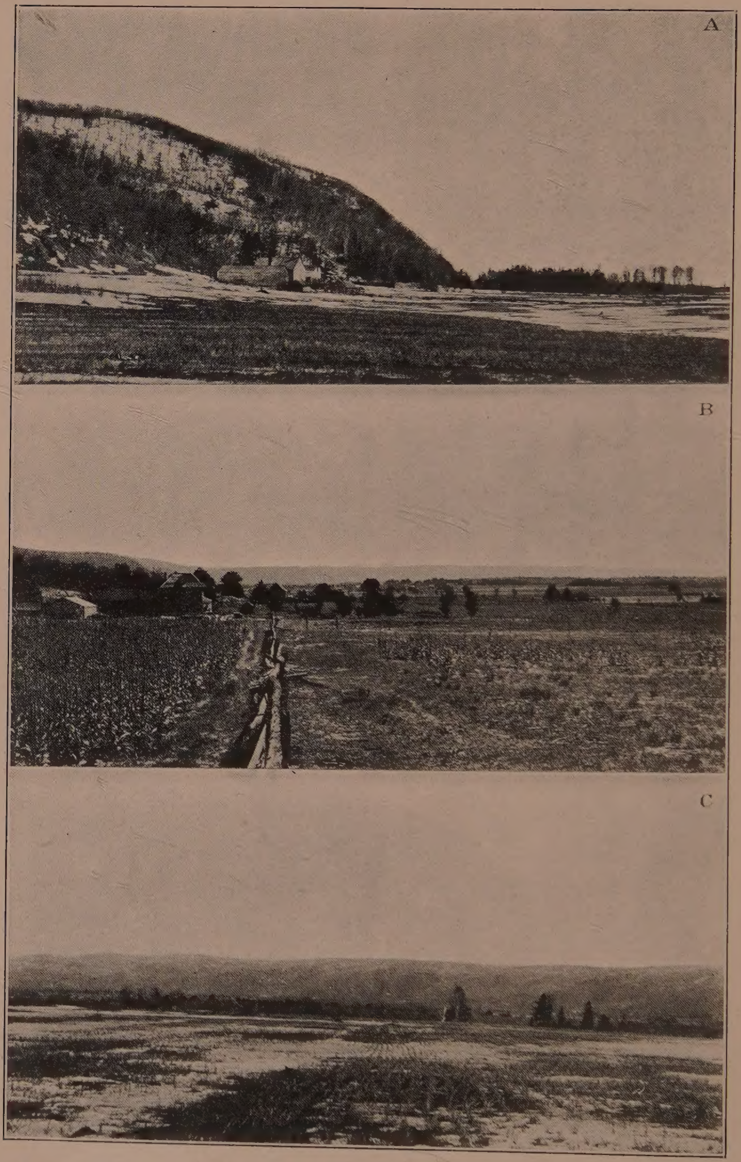

A. Laurentian escarpment south of Kings mountain, Que.
B. Lowland plain north of Quyon, Que., with Laurentian Plateau escarpment in the distance.
C. Laurentian Plateau escarpment north of Breckenridge, Que.

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GEOLOGICAL SERIES, No. 28.

Structural Relations of the Pre-Cambrian and Palæozoic Rocks North of the Ottawa and St. Lawrence Valleys.

By E. M. Kindle and L. D. Burling.

INTRODUCTION.

Eastern Canada affords no more striking physiographic feature than the scarp-like southern face of the Laurentian plateau. This northern rim of crystalline rocks rises generally from 700 to 1,000 feet above the broad, comparatively flat plain of Palæozoic rocks and marks their northern limit for 300 miles along the north side of the Ottawa and St. Lawrence valleys (Figure 1). This upland is a large uneven plateau with hummocky surface and forms part of the great expanse of Pre-Cambrian rocks to which the term Canadian shield[1] or Northern Protaxis has been applied. The Canadian shield has an area of about 2,000,000 square miles and an average elevation of about 1,500 feet above sea-level.[2] The contact between this plateau of Pre-Cambrian rocks and the plain of Palæozoic rocks forms generally a series of nearly straight or gently curving lines.

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[1] Suess, The Face of the Earth, vol. II, 1906, p. 30.

[2] Frank D. Adams, Problems of American Geology, Yale Univ. Press, New Haven, Conn., 1915, p. 47.

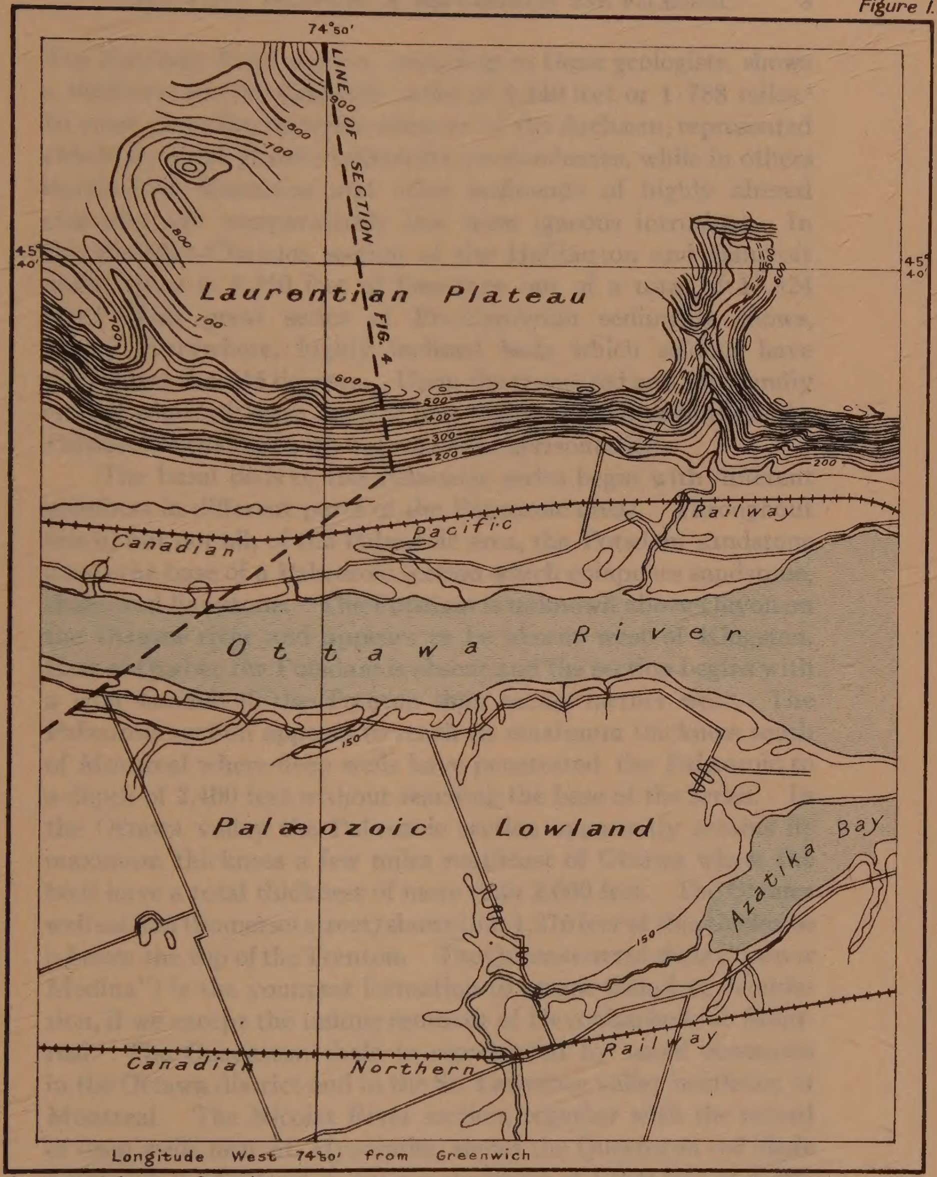
The geologic significance of a physiographic feature having so great an areal extent as this is of great interest. It has been generally regarded as part of the southern shore-line of the Pre-Cambrian nucleus of the American continent. Another interpretation of the meaning of this feature was first suggested to the authors by a cross-section of the rocks from Ottawa to Lake Erie, prepared by the junior author. The senior author has undertaken by field studies along the northern border of the Palæozoics to secure evidence bearing upon the several hypotheses which have been considered in attempting to explain the relations which subsist between the Palæozoic lowland and the Pre-Cambrian upland. The topographic contrasts shown by these two physiographic types are indicated in Plate I.

Three hypotheses appear to merit consideration in any attempt to ascertain the relations which the Palæozoic and Pre-Cambrian rocks bear to each other along the southern face of the Laurentian plateau. These are: (1) synclinal structure of the area adjacent to the southern border of the Laurentian plateau; (2) pre-Palæozoic development of the Laurentian escarpment, and (3) subsidence or normal faulting of post-Ordovician age. The evidence for and against these several hypotheses can be more clearly presented and understood after a brief consideration of the stratigraphic relations of the Pre-Cambrian and Palæozoic formations and of the known structural features of the latter.

GENERAL STRATIGRAPHIC RELATIONS.

The Palæozoic rocks south of the Ottawa river rest upon a series of Pre-Cambrian rocks from which they are separated by a great unconformity. The older series includes a wide range of types of crystalline intrusive rocks intimately associated with ancient sediments which have been subjected to intense metamorphism. The character of these Pre-Cambrian rocks is well shown both in the region immediately north of the Ottawa river and in the crystalline area to the southwest of the Ottawa-St. Lawrence Palæozoic area. In the latter region Adams and Barlow report an enormous thickness for the Archæan rocks.

Figure I.



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Escarpment topography east of Montebello, Quebec

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The Hastings Road section, according to these geologists, shows a thickness for the Grenville series of 9,440 feet or 1·788 miles.[1] In some areas the intrusive element of the Archæan, represented chiefly by great granite batholiths, predominates, while in others interbedded limestone and other sediments of highly altered character are comparatively free from igneous intrusions. In the Burleigh-Chandos section of the Haliburton and Bancroft areas, there is 8,350 feet of limestone out of a total of 17,824 feet.[2] This great series of Pre-Cambrian sediments shows, nearly everywhere, highly inclined beds which seldom have dips of less than 45 degrees. Upon the truncated and profoundly eroded edges of these ancient and highly altered sediments the Palæozoic beds rest with approximate horizontality.

The basal beds of the Palæozoic series begin with different members in different parts of the Palæozoic areas. Throughout much, but not all, of the Palæozoic area, the Potsdam sandstone forms the base of a Palæozoic section which comprises sandstone, shale, and limestone. The Potsdam is unknown above Quyon on the Ottawa river and appears to be absent west of Kingston. East of Quebec the Potsdam is absent and the section begins with a later horizon of the Trenton than occurs farther west. The Palæozoic section appears to reach its maximum thickness south of Montreal where deep wells have penetrated the Palæozoic to a depth of 2,400 feet without reaching the base of the series. In the Ottawa valley the Palæozoic section apparently attains its maximum thickness a few miles southeast of Ottawa where the beds have a total thickness of more than 2,000 feet. The Ottawa well section (Somerset street) shows that 1,276 feet of this thickness is below the top of the Trenton. The Queenston red shale ("Lower Medina") is the youngest formation to escape complete denudation, if we except the unique remnant of Devonian beds at Montreal. The Queenston shale is represented by small remnants in the Ottawa district and in the St. Lawrence valley northeast of Montreal. The Nicolet River section, together with the record of deep wells near St. Hyacinthe, shows the Queenston red shale northeast of Montreal to have a thickness of 1,000 feet or more.

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[1] Adams and Barlow, Geol. Surv., Canada, Mem. No. 6, 1910, p. 33.

[2] Idem, p. 35.

A remnant of this formation about 75 feet thick, southeast of Ottawa, has escaped complete denudation owing to its occurrence along the lower margin of a slightly tilted fault block. This Ottawa remnant of the Queenston is about equally distant from the outlier northeast of Montreal and the main mass of the formation on the south side of Lake Ontario. Both of these outliers, which have been preserved from erosion through fortuitous structural features, were doubtless originally portions of an uninterrupted extent of the Queenston shale across southeastern Ontario to the Nicolet River district in Quebec. In both New York and Quebec this formation approximates a thickness of 1,000 feet, and it is probable that it was originally represented by a comparable thickness over much of the Ottawa and St. Lawrence valleys where it is now entirely absent.

Concerning the former extent of the rocks of the Silurian system over this region nothing is known. The Devonian, however, is known to have been present in the Montreal district and it is quite possible that the whole Palæozoic section from the Potsdam to the Devonian was present over a considerable part of the Ottawa and St. Lawrence valleys.

THE PRE-CAMBRIAN SURFACE.

The hummocky or roches moutonnées character which so generally characterizes the Pre-Cambrian rocks was at one time usually ascribed to ice erosion. Laflamme was one of the first to note that in at least one district near Lake St. John "these depressions must necessarily have existed at the bottom of the Palæozoic ocean when the limestone beds were being deposited."[1] Lawson, a few years later, showed clearly that both the Palæozoic and Animikie rested on a highly irregular Archæan surface.[2] All recent observers appear to agree that the old Pre-Cambrian land surface which the Cambrian sea invaded presented topographic features essentially similar to those now found in the Laurentian areas of southern Ontario which have been recently denuded of their Palæozoic cover. Prof. Cushing, in discussing

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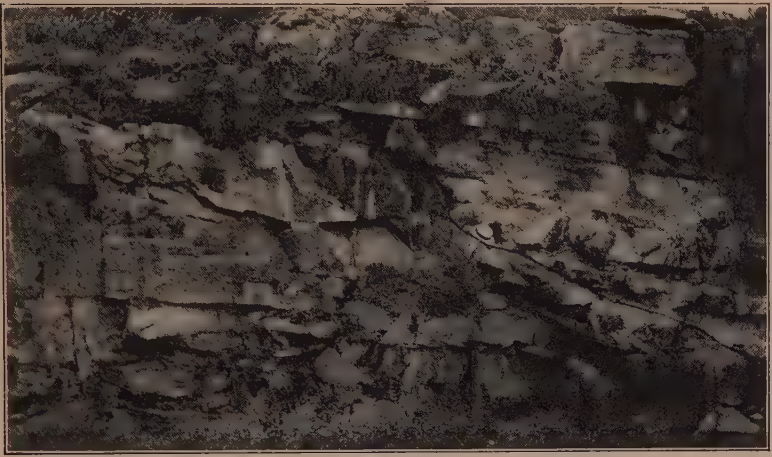
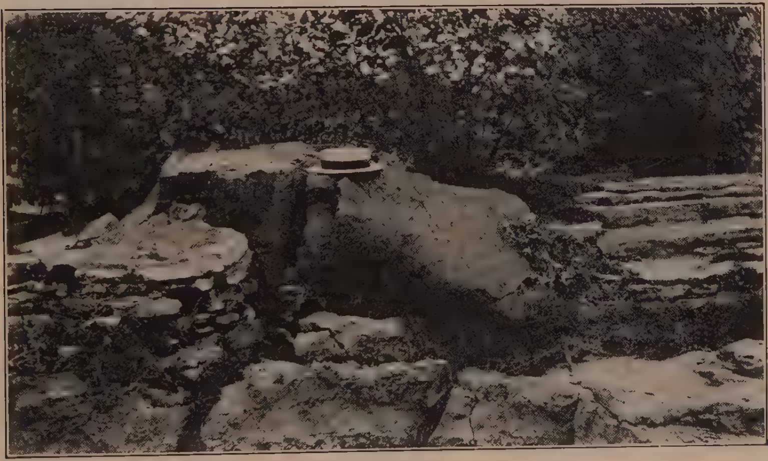
[1] Geol. Surv., Canada, Rept. Prog. for 1882, 3, 4, Pt. D.

[2] Bull. Geol. Soc. America, Vol. I, 1890, pp. 163-173.



A. Contact of granite and Ordovician limestone at Kingston Mills, Ont.



B. Granite boulder at base of Trenton limestone at Pont Rouge, Que.

the Thousand Island topography of the St. Lawrence, states that "The evidence is abundant, clear, and convincing that the Pre-Cambrian surface underneath the sandstone is precisely like that where the sandstone is absent, and that the present topography of the Pre-Cambric areas is that resulting from recent stripping away of the sandstone; in other words, that it is the reappearance at the surface of a topography of tremendous antiquity" . . . . . . "The relief of the Pre-Cambric surface under the Potsdam is much the same in character here as elsewhere along the northern and eastern borders of the Adirondacks, but is apparently less in amount than it is farther east, where there are differences in level of three or four hundred feet at least.

"Where the Potsdam has been removed the Pre-Cambric surface disclosed is one of low ridges and valleys, with general northeast-southwest trend. The ridges are low with hummocky surface, and the valleys broad and shallow and developed on the weak rocks. . . . . The extreme of relief does not much exceed 100 feet and is generally less."[1]

In central Ontario, Wilson concludes that the Palæozoic sediments "were laid down upon an uneven floor essentially the same as that presented at the present day by the Laurentian areas"[2] adjacent to the borders of the Cambrian and Ordovician rocks.

Adams and Barlow describe the character of the topography and its relation to the structure in one of the areas adjacent to the Palæozoic included in the Haliburton sheet, as follows:

"A glance at the Haliburton sheet will show the remarkable influence which the strike of rock underlying the area has had upon the distribution and position of the lakes and upon the courses of the streams. In the southern portion of the area these follow very closely the course of the bands of Grenville limestone, while in the granitic region of the north they form a delicately etched pattern on the surface of the great plain of granitic gneiss, occupying shallow depressions whose course is determined chiefly by the strike of the country rock; and even when the lake runs across the strike, the long arms and bays in its deeply indented shore line will be found to follow the directions of the foliation."[1]

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[1] H. P. Cushing, Geology of the Thousand Islands Region, Bull. N. Y. State Mus., No. 145, 1910, pp. 55, 60.

[2] A. W. G. Wilson, Trans. Can. Inst., Vol. VII, 1904, p. 153.

The testimony of Foerste indicates that the rugged Pre-Cambrian topography of southeastern Ontario persisted as far west at least as the Georgian Bay district. He states[2] that at Granite island "residual masses of Lowville are preserved in pockets worn out of the granite in times preceding the Lowville deposition. The former topography, therefore, in Pre-Cambrian times must have been that of a series of parallel ridges, consisting chiefly of quartzite, but including also other rocks. The general trend of these ridges was either west or south of west. The general dip of these ridges at present is toward the west, so that the crests go below water level in that direction, and this may have been the direction of their dip also in early Palæozoic times. Later these ridges were lowered below sea-level. The earliest deposition so far recorded in this area belongs to the lower Lowville. The northern ridges may have been entirely covered before the close of the Trenton, but some of the most southern ridges, in the vicinity of Sheguindah, apparently were not entirely below water level before the deposition of the Collingwood." Erosion has completely removed the Palæozoic rocks over a considerable area north of the head of the St. Lawrence river. On the borders of this area remnants of the Palæozoics afford evidence of the highly irregular and hilly character of the surface on which the earliest Palæozoic rocks of the region were laid down.

Perhaps no area affords clearer evidence of the character of the Pre-Cambrian relief than the Kingston district. Fort Henry hill, a promontory rising about 100 feet above the St. Lawrence river, just east of Kingston, may be cited as an example of the hilly character of the Pre-Cambrian topography in Ontario. This is a granite hill with a thin veneer of Ordovician limestone which has been almost entirely removed from the eastern side. A remnant of the limestone is still to be seen, however, at water level at the head of the bay on the east side of the hill and another patch is preserved at a higher level on the same side where the slope of the hill is very steep. The exposed crest of the ridge is granite, but patches of limestone overlie the granite a very few feet below the highest point. On the west slope most of the limestone cover remains, the beds nearest the granite often adjusting themselves to its slope. At Kingston Mills, 5 miles northeast of Kingston, a railway cut just west of the canal affords an excellent exposure of the contact between the Ordovician limestone and the Archæan. The steep slope of the Pre-Cambrian hill surface exposed in this cut is shown in Plate II, A. There is no residuary clay between the Archæan and the Palæozoic, but the limestone at the contact includes coarse angular sand and gravel of quartz and feldspar, and boulders of granite similar to the one exposed on the north side of the cut at Kingston Mills are of frequent occurrence. The largest of these boulders which has been observed occurs in the basal beds of the Trenton in the Jacques Cartier river at Pont Rouge, Quebec. It has a maximum length of 8 feet 4 inches and rises 2 feet above the partially enclosing horizontal limestone strata (Plate II, B), which dip away at angles of from 15 to 20 degrees in the immediate vicinity of the boulder. The fresh character of the Pre-Cambrian surface and the absence of residuary clays at its contact with the overlying Palæozoic are in marked contrast to the conditions reported in Wisconsin where deposits of clay 10 to 20 feet thick and consisting of decomposed Pre-Cambrian rocks separate the Cambrian from the Pre-Cambrian.[1]

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[1] Intern. Geol. Cong., Geol. Surv., Canada, Guide Book No. 2, 1913, p. 13.
[2] Manuscript.

Throughout a considerable area of the Pre-Cambrian rocks northwest of the head of the St. Lawrence the orientation of the lakes and streams conforms largely to the strike of the highly inclined Archæan rocks. The strike valleys are doubtless chiefly the product of Pre-Cambrian erosion in beds of softer schists or zones of interbedded crystalline limestone, although they are now partially filled by drift and may have been somewhat modified by glacial action.

The foregoing summary of the observations and opinions of various geologists regarding the character of Pre-Cambrian topography in Ontario indicates that the transgressing seas of

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[1] S. Weidman, Jour. Geol., Vol. XI, 1903, p. 311.

Cambrian time enveloped an Archæan land surface of highly irregular character but of moderate relief. It is probable that the higher hills of that topography seldom rose more than 300 or 400 feet above their adjacent valleys. The section (Figure 6), from the Ottawa river to Lake Erie across the Ontario peninsula, indicates clearly the entire absence of any discordance in the general profile of the pre-Palæozoic surface in that region, and there is no evidence of the existence elsewhere in the Pre-Cambrian topography of any marked or abrupt changes in the general level of the land such as that marked by the southern escarpment of the Laurentian plateau. The irregularly etched surface of the old Pre-Cambrian land, therefore, affords no explanation of so unique a topographic feature; and this discrepancy is all the more apparent when we realize that this escarpment abruptly truncates the regularly oriented structural features of the region (see page 12).

STRUCTURE OF THE PALÆOZOIC PLAIN.

The great expanse of Palæozoic lowland which borders the Ottawa and St. Lawrence valleys for 200 miles is separated from the Palæozoic area of the Ontario peninsula by a belt of Pre-Cambrian rocks, very narrow at the head of the St. Lawrence but widening rapidly to the northwest. This area of Archæan rocks emerges like an island from the low-lying Palæozoic cover to the east and to the southwest, a relationship which is clearly shown by the cross-section, Figure 6. That this shield-like uplift took place subsequent to the time of Ordovician sedimentation is indicated by outliers of the Ordovician such as that at Clear lake.[1] This outlier rests upon the Pre-Cambrian at an elevation about 830 feet A.T., while on either margin of the Archæan shield sediments of the same age are found at elevations of 100 or 200 A.T., and these pass below sea-level toward the southwest, east, and northeast. On the east, owing chiefly to faulting, the elevation of these beds varies widely in different places; but to the southwest they decline, along the line of section (Figure 6), at a uniform rate of 12½ feet per mile until, at Toronto, the base of the

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[1] Ann. Rept. Geol. Surv., Canada, Vol. XIV, 1904, p. 7J.

Trenton lies nearly 1,000 feet below sea-level. This gives a difference in the present altitude of the base of the Ordovician rocks at Clear lake and Toronto amounting to about 1,800 feet. If the Ontario Archæan shield, extending from the Lake Nipissing district to the head of the St. Lawrence, antedates Palæozoic sedimentation in origin, the remnants of these sediments now found near its centre should be of much later age than those which lie around its margin; but, as shown by the Clear Lake outlier, this is not the case. The only inference which can be drawn from the known facts of areal distribution and age of the sediments in this region is that the Nipissing-Kingston uplift is of late Palæozoic or Post-Palæozoic origin.

The Palæozoic plain of the Ottawa and St. Lawrence valleys lies between the Laurentian plateau on the north and the Adirondack uplift on the south, and extends eastward from the Archæan shield at the head of the St. Lawrence to the zone of Appalachian folding east and southeast of Montreal.

The Palæozoic sediments which underlie the surface of this plain over a considerable part of the area have a thickness of from 2,000 to 3,000 feet, a section which probably represents only a fraction of the original thickness of the Palæozoic. Indeed, the remnant of Devonian rocks at Montreal[1] and various outliers of the Palæozoic furnish conclusive evidence of this fact.

Subsidence or normal faulting is a structural characteristic of the Palæozoic rocks throughout the northern part of this lowland. Numerous faults, of which the one at Montmorency falls with a throw of 600 feet[2] is an example, are present in the eastern part of the region. In the Ottawa valley the sedimentary rocks are cut by numerous faults, many of which have been described by Ells[3] and shown on maps of the Geological Survey, Canada. Various other faults, some of which have considerable lateral extent, are known to the writers, and many minor faults are doubtless concealed by the heavy mantle of drift and marine clays which covers the buried channel of the Ottawa river to a depth of 100 to 200 feet.[1] Nine faults are shown on the Ottawa sheet alone, which includes a Palæozoic area about 16 by 22 miles in extent. The position of some of these faults and the location of the cross-sections which have been drawn are indicated in Figure 2. The largest of these is the Hull and Gloucester fault which has a maximum throw of about 1,850 feet.[2] This fault is the major structural feature of the Palæozoic area south of the Ottawa river and can be traced for a number of miles east of Ottawa. Two other faults lying between this fault and the Ottawa river have throws which approximate 250 and 350 feet respectively. The structural relations of these faults to each other and to the Palæozoic rocks east of Ottawa are shown in the cross-section, Figure 4. It is due chiefly to the Hull and Gloucester fault that the Queenston has been dropped sufficiently low for a remnant of it to be preserved from erosion in the vicinity of Vars, a few miles southeast of Ottawa. Another section, Figure 3, shows the principal faults in a section running south from Kings mountain across the Ottawa valley west of Ottawa. In the vicinity of the faults the strata nearly everywhere show strong dips, which, however, die out a short distance from the fractures. Elsewhere, as far east as the zone of Appalachian folding, the strata approach general horizontality. The numerous faults which cut the Palæozoic beds of the Ottawa and St. Lawrence Valley province distinguish it structurally from the Palæozoics of the Ontario peninsula. In the latter district no faults of note are known and the beds show a very gentle monoclinal dip to the southwest. The cross-section (Figure 6) which extends from the shore of Lake Erie south of St. Thomas to the Laurentian plateau east of Ottawa brings out clearly the fact that the Ottawa River valley lies in a zone of faulting, while the area to the southwest of the Kingston and Lake Nipissing Archæan shield is free from faults. The profile of this section was compiled from the topographic maps of the Militia Department and from railway surveys. The geology

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[1] Harvie; Canada, Roy. Soc., Proc. and Trans., 3d. ser., Vol. 3, sec. 4, pp. 249-299, 14 pls., 3 figs. 1910.

[2] Raymond; Int. Geol. Cong., Geol. Surv., Canada, Guide Book No. 1, 1913, p. 40.

[3] The physical features and geology of the Palæozoic basin between the Lower Ottawa and St. Lawrence rivers, R. W. Ells, Trans. Roy. Soc. Canada, Vol. 6, Sec. 4, pp. 99-120, 1900.

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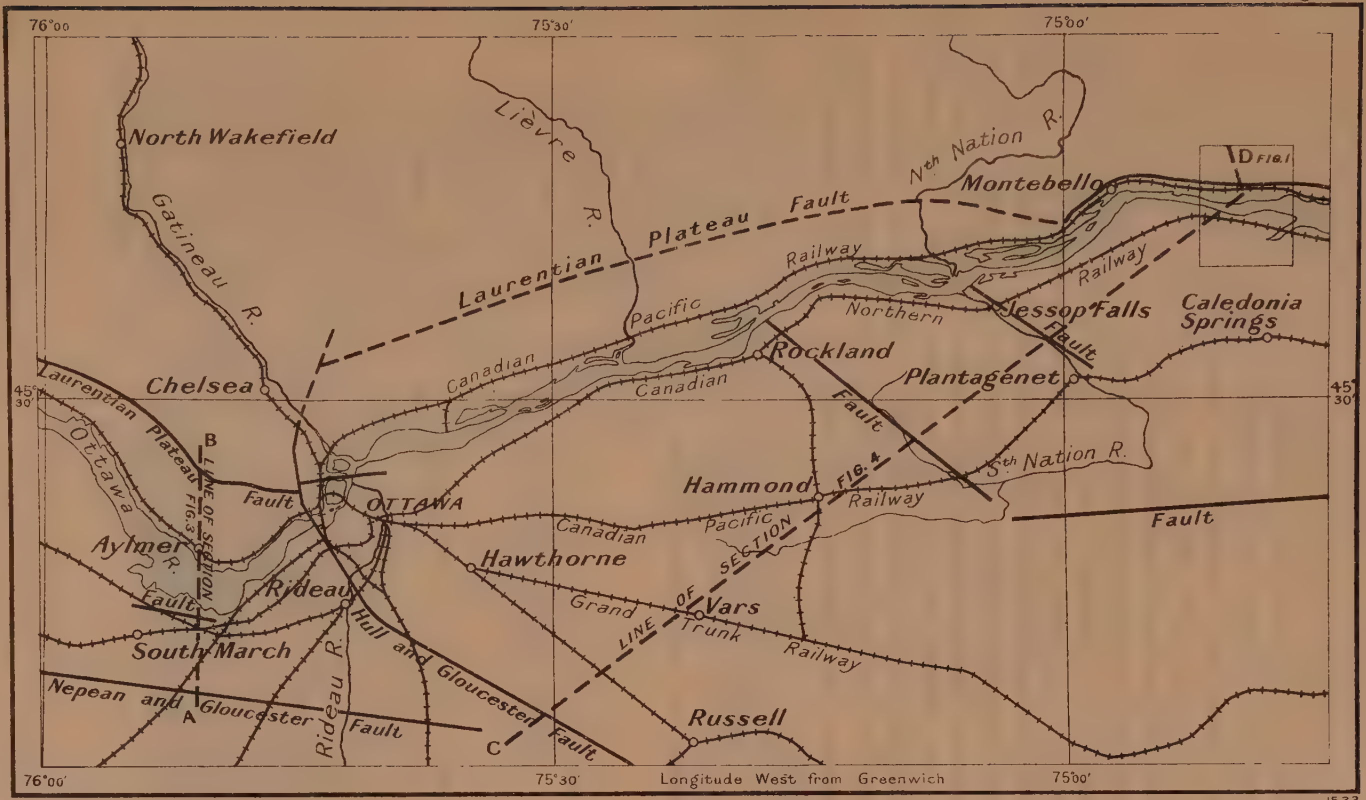
[1] Idem, p. 105.

[2] R. W. Ells, Geol. Surv., Canada, map sheet 120.

Figure 2.



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Outline map of the **Ottawa District** showing principal faults and lines of cross-sections

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east of the central Pre-Cambrian area was derived in part from the Ottawa and Cornwall (No. 120) and the Grenville (No. 121) sheets of the Geological Survey, Canada, and in part from new field observations. Southwest of this central Pre-Cambrian area the geology was derived from well records.[1]

The vertical scale of the cross-section is such as to greatly magnify the dips. The extent of the exaggeration is indicated by the statement that the dip west of the central Pre-Cambrian area is only 12½ feet to the mile. The more northerly and northeasterly province cut by this section clearly represents a zone in which faulting is the most striking and characteristic structural feature, while the more southerly province lies outside this zone.[2] It must be noted, too, that the faulting of the Ottawa and St. Lawrence plain is localized and apparently confined chiefly to its northern portion. This fact was pointed out by Ells, who, in speaking of the belt of Palæozoics bordering the St. Lawrence east of Brockville, states that "if faults exist in the district their extent must be quite limited................."[1]

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[1] Well records used were derived from the following sources, the authors being indebted to Mr. Wyatt Malcolm of the Geological Survey for the use of his manuscript compilation of the well records of Ontario and Quebec:

Whitby: Brumell, Ann. Rept. Geol. Surv., Canada, Vol. V, 1893, p. 24Q.
Highland Creek: Brumell, loc. cit., p. 24Q.
York township, lot 11, con. III: Ingall, Ann. Rept. Geol. Surv., Canada, Vol. V, 1893, p. 107 SS.
Toronto: Brumell, loc. cit., p. 25Q.
Swansea: Brumell, loc. cit., p. 25Q.
Mimico: Brumell, loc. cit., p. 26Q.
New Toronto: Ingall, Ann. Rept. Geol. Surv., Canada, Vol. VI, 1895, p. 109S.
Clarkson: Files of Water and Borings Division, Geol. Surv., Canada.
Hamilton: Coste, 15th Rept. Bur. Mines, Ontario, 1906, p. 112.
Dundas: Brumell, loc. cit., p. 31Q.
Brantford: Coste, loc. cit., p. 112.
Beachville: Files of Water and Borings Division, Geol. Surv., Canada.
St. Thomas: Depth only record available.

[2] It may be noted here that Wilmott (Jour. Geol., vol. XI, 1900, pp. 40, 42) has inferred the existence of a fault extending from the southeastern border of the Adirondacks to the northern end of Lake Nipigon. Since, however, the author of this paper disclaims personal familiarity with the southeastern part of the region traversed by this fault and presents no specific evidence for its existence in the district northwest of the head of the St. Lawrence, the only part of its course with which we might be concerned in this paper, it has not seemed advisable to include it in the present discussion. In this region the field evidence seems to be decidedly against the existence of such a fault. For a discussion of the effect of local faulting around the eastern borders of the Adirondack region the reader is referred to papers by Prof. J. F. Kemp and Prof. W. M. Davis (Popular Sci. Monthly, Mar. 1906; Science, vol. XXIII, 1906, pp. 630-632.

THE LAURENTIAN PLATEAU ESCARPMENT.

The general topographic relations of the Palæozoic and Archæan areas are those of a lowland lying at an average elevation of about 1,000 feet below an adjacent plateau whose surface is irregular, but whose sky-line is, in places at least, exceedingly even (see Plate I, C). Northwest of Montreal, the surface of the Laurentian plateau is estimated by Adams[2] to have an average elevation of from 1,000 to 1,500 feet, the adjacent lowland standing 100 to 300 feet above tide. North of Quebec the summit of Roundtop, which marks the southern border of the plateau in that vicinity, attains an elevation of 1,600 feet (barometer). Near Ottawa, Kings mountain rises just north of the scarp to an elevation of 1,220 feet, the lowland to the south having an elevation of from 200 to 300 feet. Many points on the plateau a few miles north of its southern border attain somewhat greater elevations. In the region north of Ottawa the elevation of the plateau at the Hudson Bay divide only slightly exceeds that of the higher points like Kings mountain near the escarpment. The height of the divide itself, over the area covered by Wilson's[3] map, generally lies between 1,000 and 1,400 feet. Farther east the plateau is somewhat higher. One of the highest points in this more easterly region is Trembling mountain, 2,380 feet, which is located about 35 miles north of the southern border of the plateau.

The small topographic map, Figure 1, represents an area in the lower Ottawa valley where the typical relations of the northern border of the Palæozoic lowland and the Laurentian plateau are shown. This representative bit of topography shows the almost perfectly flat Palæozoic plain meeting the steep scarp face of the southern margin of the Laurentian plateau in a nearly straight line. Along portions of the escarpment the con-

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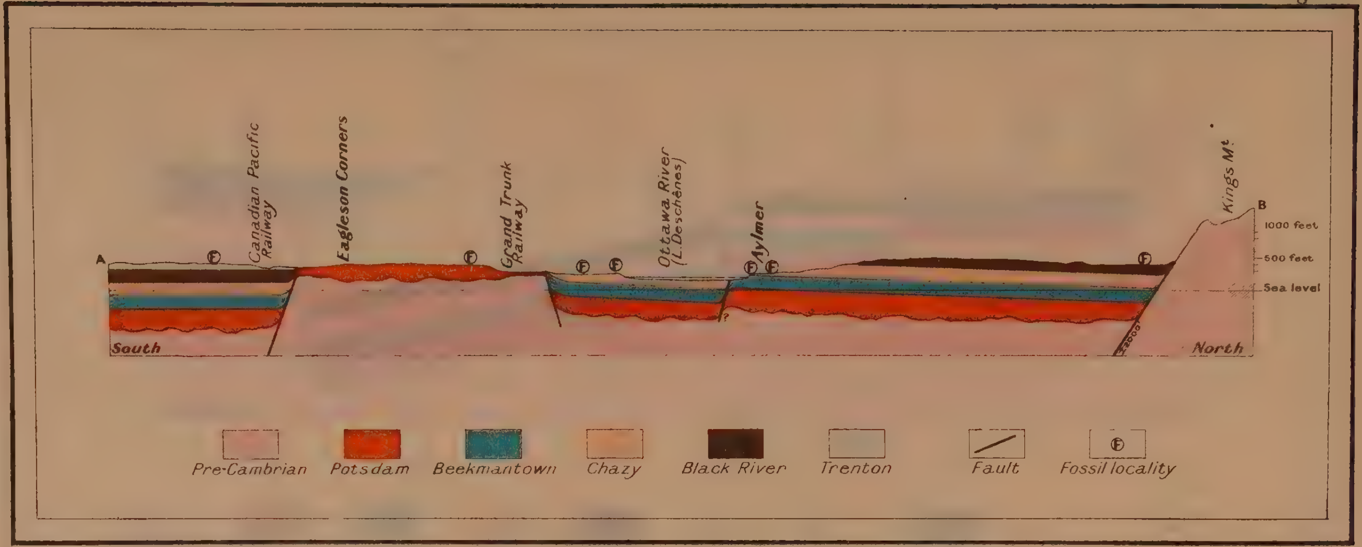
[1] Trans. Roy. Soc. Canada, vol. 6, sec. 4, 1900, p. 118.

[2] Ann. Rept. Geol. Surv., Canada, new ser., Vol. VIII, 1894 (1897), p. 8J.

[3] Geol. Surv., Canada, Mem. 4, 1910.

Figure 3.



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Cross-section from **Kings Mountain** through **Aylmer, Quebec**

Horizontal Scale

1 ½ 0 1 2 3 4 5 Miles

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tact of the older and younger series of rocks is marked by terraces of marine clays which in some degree conceal the abrupt transition from a plain to a plateau scarp. At some points offset faults to the north or south appear to have interrupted the continuity of the scarp. A combination of these two features in the district immediately north and northeast of Ottawa obscures the abrupt and generally observable contact of the two topographic types. Northwest of the lower Gatineau valley the Laurentian escarpment continues uninterruptedly for nearly 20 miles, rising 800 to 1,000 feet above the lowland at its base. The irregular character of the Pre-Cambrian topography has already been pointed out (pages 4-8). Denudation of the Palæozoic rocks has uncovered this ancient hilly topography in many places along the northern border of the present Palæozoic plain, so that the Palæozoic plain is sometimes separated from the base of the plateau by a border of irregular Archæan hills. These hills of granite and schist occasionally have an elevation of 200 or 300 hundred feet, although generally less, above the adjacent Palæozoic rocks. Where hills of this type are present the south-facing escarpment of the Laurentian plateau may be obscured, but its position is generally easily recognized by a pronounced change in the relief.

INTERPRETATION OF THE DATA.

In the preceding pages we have shown that the Laurentian plateau, for approximately 300 miles, rises abruptly several hundred feet above the Palæozoic plain and that a zone in which faulting is the dominant structural feature borders this escarpment on the south. We will now consider the significance of this topographic discordance and of the associated structural features.

The possibility of synclinal structure affecting both the Palæozoic and Archæan series at once suggests itself, to one unfamiliar with the field relations, as an explanation of the Laurentian escarpment. When it is pointed out, however, that the older series has been highly folded and that the general trend of this folding is across the course of the escarpment and in many cases at right angles to it, the improbability, if not impossibility, of this hypothesis becomes manifest. If synclinal structure were a competent explanation a consequent general southerly inclination of the beds north of the areas of maximum thickness would manifest itself in the numerous outcrops along the Ottawa river. In all of the outcrops known to the writers, however, the beds are horizontal or nearly so, except in the immediate vicinity of faults. In the section passing through Aylmer the general dip is even to the north. Near faults the dips, though often heavy for short distances, die out in a few yards or rods. Examination of the accompanying sections will show that most, if not all, of the declination of the beds is due to normal faults. The assumption of a synclinal trough structure could in no degree explain the scarp-like face which marks the southern border of the Laurentian plateau.

We may next consider the hypothesis of the development in pre-Palæozoic times of a Laurentian escarpment bordering the Palæozoic lowland. Such a feature cannot be assumed to be the possible product of folding or down-warping in Pre-Cambrian times, for, as noted above, the general strike of the crystalline rocks is everywhere transverse to the line of the scarp. Any trough-like structure which might have been developed through folding or the differential erosion of folded strata would have a northeast and southwest trend instead of the general east-west course of the northern border of the Palæozoic rocks. If pre-Palæozoic faulting is assumed to have produced the escarpment as the northern rim of a graben type of depression, as suggested by one author[1] for the Montreal district, it will be profitable to consider the conditions under which scarps may be developed in connexion with faults. In the southern Alleghanies, faults with throws of from 5,000 to 8,000 feet cut the Palæozoics and are not betrayed by the slightest physiographic evidence. The great faults in southwest Virginia may be cited as an illustration of the general principle that faults result in scarps only when beds of unequal hardness are exposed to erosion. If faulting had occurred in the Archæan rocks along the present plateau border line before they received a cover of Palæozoic sediments the strata on either side would have been of precisely the same lithologic type and no surface feature in any way comparable with the present scarp could have resulted. Pre-Cambrian faulting, therefore, fails as an explanatory hypothesis of the origin of the scarp.

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[1] A. W. G. Wilson, Jour. Geol., Vol. XI, 1903, p. 620.

If, however, we assume that the transgressing Cambrian sea found no interrupting wall or line of cliffs where the southern margin of the plateau now stands, and that its sediments and those of succeeding Palæozoic seas overspread the Archæan rocks of the present Laurentian plateau, then conditions were ideal for the production of an escarpment in the event of profound faulting followed by long continued denudation. Conspicuous physiographic evidence of such a fault would probably begin to appear only after erosion had removed the Palæozoic beds on both sides down to the level of the uppermost Archæan. After denudation had reached this level its progress would be immeasurably more rapid on the south or downthrow side. The major part of the beds to the south of the fault line being limestone, and to the north quartz and feldspar, their rate of degradation would be roughly proportional to the resistance to erosion and solution offered by limestone on the one hand and granite on the other. The inevitable result of such differential erosion would be an escarpment of Archæan rocks, though this would be interrupted by irregularities in the original topography. Such irregularities are rather common along the southern front of the plateau just as they are in the more recently and less completely uncovered Pre-Cambrian topography of the region about the head of the St. Lawrence. Like the latter they doubtless in many cases represent inequalities in the Pre-Cambrian land surface and some of them probably represent minor faults transverse to the main line of faulting.

It will be seen from the foregoing considerations that, while Pre-Cambrian faulting would have been inadequate, normal faulting in the latter part of the Palæozoic, or later, would have been entirely competent to produce this escarpment which the authors consider to represent a fault line scarp.[1] Post-Cambrian faulting appears to be the only inference which accords fully with all the evidence. The escarpment is located along the northern border of a zone in which subsidence faulting is known to be a common and characteristic structural feature. The character of the topography along the southern border of the Canadian shield north of the St. Lawrence and Ottawa valleys is quite different in character from that along its western border. Along the shores and on the islands of the southern half of Lake Winnipeg the Palæozoic and Archæan rocks approach each other rather closely for nearly a hundred miles, but the latter shows little if any greater relief than the former. Archæan rocks form the eastern and Palæozoic rocks the western shore of this long shallow lake throughout its entire length of 250 miles. Along the eastern border of Lake Winnipeg, the Archæan generally occurs in the form of low rounded knobs of granite, few of which rise more than 50 feet above the lake. At the north end of the lake the actual contact of the two systems is covered by drift, but the general level of the westernmost exposures of the Archæan, near Warrens Landing, is lower than that of the near-lying easternmost exposures of the Palæozoic. In the region still farther north and northwest, geologists familiar with the country report a similar absence of marked topographic discordance between the areas underlain by Palæozoic and Archæan rocks. Outside of the Ottawa and St. Lawrence Valley region any escarpment is apt to be on the Palæozoic side of the contact. The Archæan-Palæozoic contact, which extends west from Kingston to Georgian bay, shows the same topographic contrast with the Laurentian Plateau escarpment as the one just described between the latter and the western border of the Archæan. Here the uniform relations of Pre-Cambrian highland and Palæozoic lowland found north of the Ottawa and St. Lawrence rivers are often reversed, for the Ordovician limestone frequently forms a more or less pronounced cliff overlooking a Pre-Cambrian area of less relief.

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[1] The reader is referred to a paper by Prof. W. M. Davis (Science, N. S., vol. XXVI, pp. 90-93, 1907) for a discussion of the terms fault scarp and fault line scarp.

This relationship of the two series of rocks occurs southeast of Madoc, where the Ordovician limestone on the south side of Moira lake forms an escarpment rising 150 feet above the lake and considerably higher than the granite area on the opposite side. Similar topographic relations between these two rock series exist northwest of Madoc and west of Belmont lake where the retreat of the Ordovician limestone through denudation has left walls of cliffs standing higher than the adjacent Pre-Cambrian. These examples will suffice to show the markedly different types of topography which denudation has developed on very similar groups of rocks in areas which are geographically only slightly removed from each other. The differences are evidently to be explained by corresponding variations in the structure. The operation of ordinary processes of erosion alone will not explain the very different topographic features exhibited by the western and southeastern borders of the "Protaxis". The escarpment-like border shown by the Archæan in the latter region can only be explained on the assumption that denudation has there been aided by profound faulting.

Evidence which strongly corroborates, if it does not alone demonstrate, the validity of the inference of faulting, is furnished by the areal relations of the Palæozoic and Pre-Cambrian. The contact of these two rock series along the Ottawa River valley has been mapped by the Geological Survey, Canada, on a scale of 4 miles to 1 inch, and the contact is there shown, throughout its course, as a straight or gently curving line. The Archæan area is nowhere invaded by tongues or projecting angles of Palæozoic rocks such as would certainly be present if faulting had not substituted an approximately straight contact for the usual highly irregular contact resulting from the denudation of beds so unlike as the Archæan and Palæozoic. The highly irregular type of contact which develops between these rock groups under normal conditions and in the absence of faulting is seen in the maps by Miller and Knight[1] showing the Palæozoic-Archæan boundary in the region northwest of Kingston; but this irregular zigzag type of contact is unknown along the border of the Laurentian plateau. The senior author has examined several areas where stream valleys cross from the Archæan to the Palæozoic, in order to discover, if possible, a single case where the Palæozoic extends up a valley into the Archæan area; but no such case has been found and the contact appears to be everywhere a series of approximately straight or gently curving lines.

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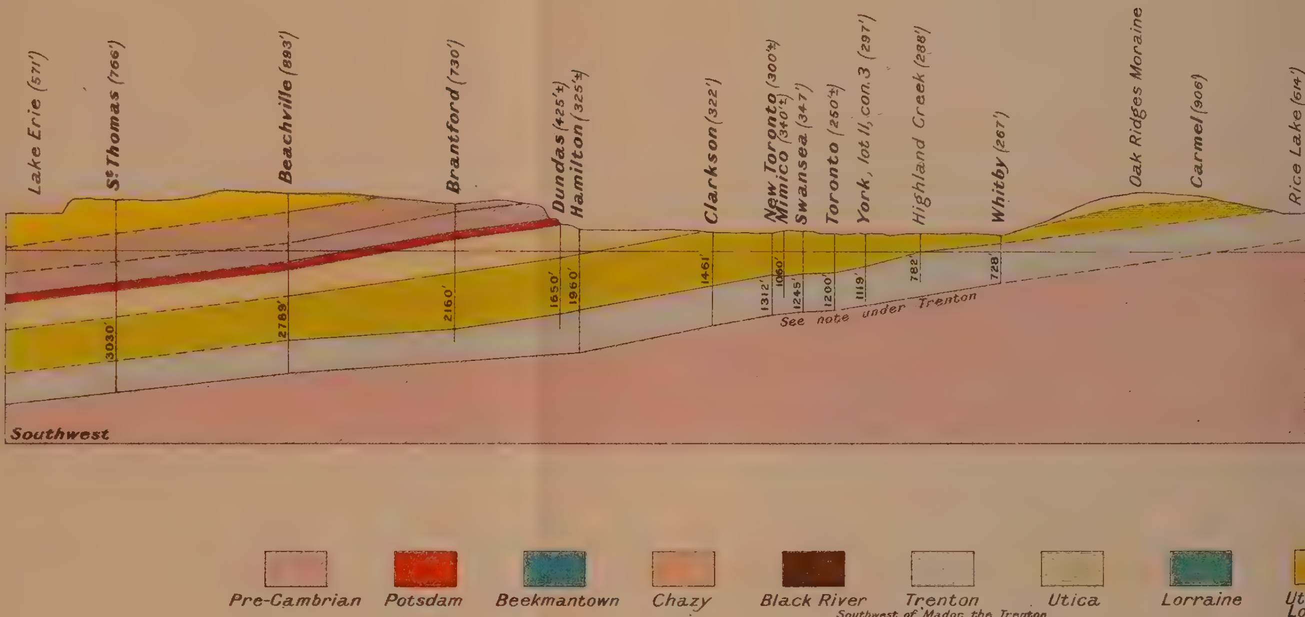
[1] Rept. Ontario Bur. Mines, vol. XXII, pt. II, 1914.

Another class of facts which may be considered in this connexion is the lithologic character of the limestones at or near their northern border. The Trenton limestone at Ottawa is a nearly pure limestone entirely free from sand, pebbles, or other detrital material which the granite hills rising a thousand feet above its border must have supplied to it if these hills formed the northern boundary of the Trenton sea. The freedom from detrital material of this and other limestones of the Ottawa section is one of many facts which indicate that the present topographic relations between the Palæozoic and Archæan series are the result of faulting subsequent to their formation. The position of the fault which is responsible for this topographic inequality is shown in Figure 5. It may be conveniently designated as the Laurentian Plateau fault, since it marks the southern margin of this upland throughout the area in which it impinges on the Palæozoic rocks. At Quebec, it approaches very near to the line of the St. Lawrence and Lake Champlain fault, the two being almost parallel and lying only a few miles apart northeast of the city. The Laurentian Plateau fault is supposed to pass into the river below the Island of Orleans. North of the city of Quebec the southern border of the plateau is broken up by valleys into a series of more or less detached hills. Roundtop, which is representative of these, has an elevation of 1,600 feet (barometer). The Palæozoic plain has here a width of only 4 or 5 miles; Archæan hills 1,200 to 1,600 feet high limit the plain on the northwest, and a tableland comprised chiefly of the highly deformed Sillery beds borders it on the southeast. This plain rapidly widens in ascending the St. Lawrence valley above Quebec. Between Quebec and St. Anne river the line of the fault is believed to lie north of the margin of the Palæozoic, as shown on the map, at the foot of the line of high Archæan



Southwest of Madoc the Trenton may include Beekmantown, Chazy, and Black River. It is separated from the Pre-Cambrian by arkose or sandstone in the following borings:– Whitby(8'), York(10'), Toronto(20') and New Toronto(72')

Geological Survey, Canada

Cross-section from the **Laurentian Plateau**

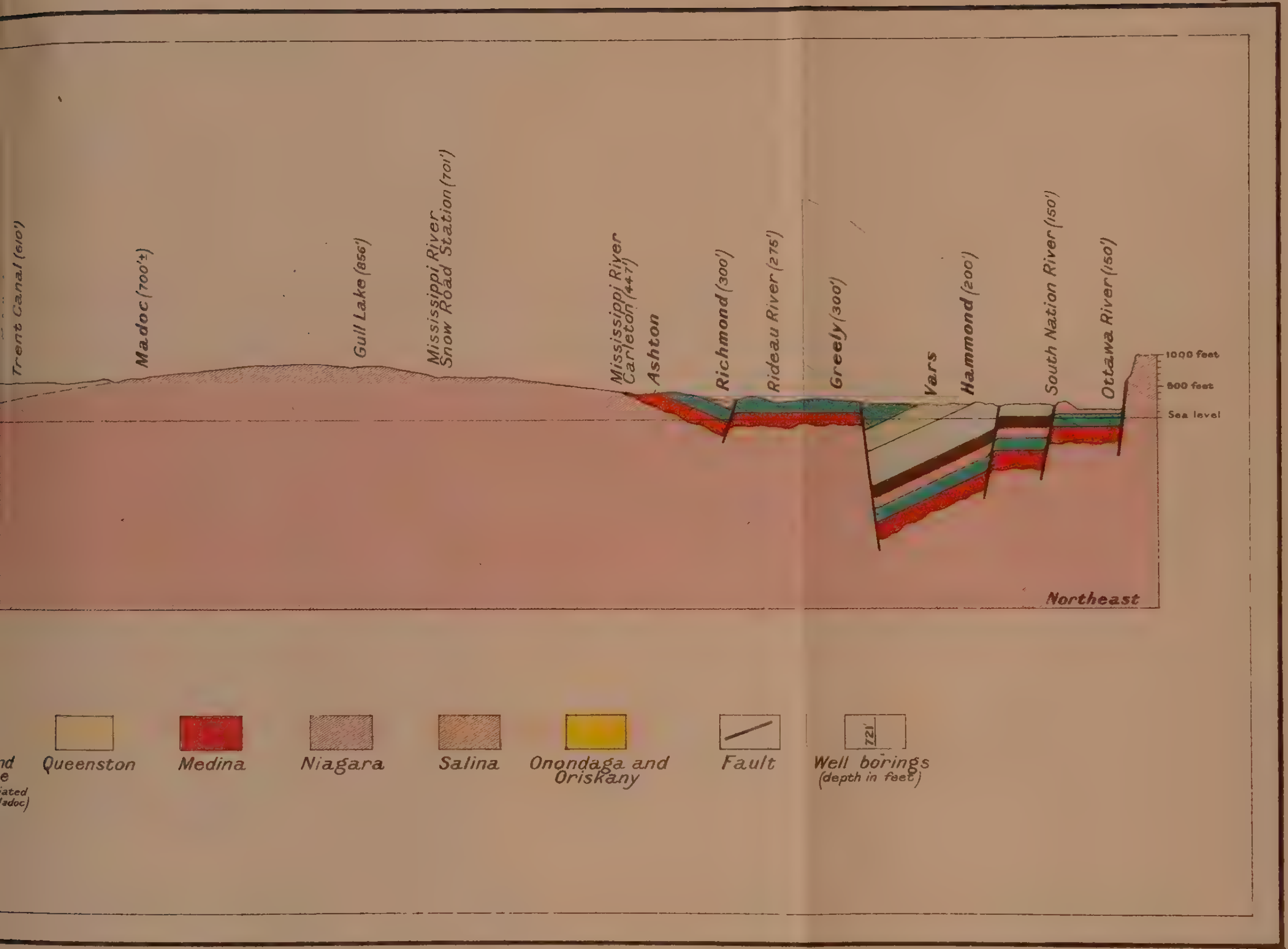
The line of section in the Ontario Peninsu

To accompany Bulletin by
E.M.Kindle and L.D.Burling

Horizontal

10 5 0 10 20 30

Figure 6.



1527

Lake Erie at St. Thomas, Ontario

s about normal to the strike

Location of Section shown on Fig. 5.

50 60 70 Miles

hills. The two conspicuous tongues of Archæan which indent the Ordovician east and west of Jacques Cartier river are very much lower than the main front of the Laurentian plateau and probably represent hills in the old Pre-Cambrian surface such as have been described in the first part of this paper. Similar granite hills which lie south of the line of fault are locally conspicuous in the Ottawa River valley above Quyon. The western extent of the fault is unknown. North and northwest of Chichester P.O., which is the most westerly point visited, the Laurentian plateau terminates in a scarp or line of hills which rises with about the same abruptness and relative elevation above the country to the south as in the lower Ottawa valley.

FORMER EXTENT OF THE PALÆOZOIC.

The interpretation of the relationship of the Palæozoic plain to the Laurentian plateau which has been set forth above is one which requires a very material alteration of the current view of the former extent of some of the Palæozoic rocks in the extensive region north of the St. Lawrence and Ottawa rivers. The great V-shaped area of Archæan rocks, which embraces the Hudson Bay depression and extends southward from the Arctic coast on the west and from northern Labrador on the east to the Ottawa and St. Lawrence rivers and the upper Great Lakes, has long been considered to represent the approximate outlines of a Pre-Cambrian continent, which persisted through Palæozoic time. Dana, who appears to have been the original exponent of this conception of the Pre-Cambrian continent, gives his reason for believing that the lands of this area were above sea-level, in the following words: "They are concluded to have been thus dry because no marine beds cover them, while on either border marine beds (Silurian and later) commence and spread widely over the most of the continent."[1] In view of the extensive denudation which most lands of the present are now known to have suffered, the mere absence of a formation or formations cannot be admitted as good evidence that they may not have been present at some earlier period. With few exceptions, however, later writers on palæogeography have accepted and followed more or less closely Dana's delineation of the permanent character of the Azoic continent. A few geologists have not accepted this view. Lawson, after reviewing the available evidence, concludes that "the surface of the Archæan 'nucleus' was once very extensively if not wholly covered by Palæozoic sediments."[1] Willis should also be noted as opposing it. He states, in speaking of the Archæan protaxis, that "It was submerged probably beneath the general Cambro-Ordovician transgression and certainly to a great extent beneath the Siluro-Devonian seas which spread over Arctic Lands."[2] Most of the maps of the Palæozoic seas make their shore-lines more or less coincident with the north side of the St. Lawrence and Ottawa rivers. The recognition of the Laurentian escarpment as a fault plane, however, leaves no ground whatever for continuing to draw palæogeographic strand lines at or near this line. A diagrammatic restoration of the relations of the Archæan of the Laurentian plateau and the Palæozoic of the St. Lawrence lowland, which existed before faulting, will show that 2,000 to 4,000 feet of Palæozoic rocks overspread the southern border of the present Laurentian highland. Such a considerable thickness of sediments overlapping the Archæan points unmistakably to a very considerable extension, toward the north and beyond its present margin, of the seas of Palæozoic time.

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[1] Dana, J. D., Manual of Geol., Rev. Ed., 1868, p. 136.

A partial reconstruction of the Montreal section as it existed previous to the extensive denudation which has developed the Palæozoic plain is highly instructive in this connexion. A remnant of horizontal Trenton limestone is preserved on the slopes of Mount Royal, the highest beds having an elevation of about 500 feet. The thickness of the Utica-Lorraine in the region adjacent, according to Adams and Leroy,[3] is about 2,300 feet. This is doubtless a conservative figure since Foerste, in the region to the northeast, gives these beds a considerably greater thickness. Well records in the St. Hyacinthe district show the Queenston to have a thickness of not less than 1,000 feet. The total thickness of beds lying above the Trenton in the Montreal section is, therefore, about 3,300 feet. These beds superimposed on the Trenton of the Mount Royal section would give a Palæozoic section rising 3,800 A.T. If for the moment we neglect the existence of the Laurentian Plateau fault and project this 3,300 feet of sediments on the section constructed by Adams and Leroy[1] the top of the Palæozoic section at Montreal would stand more than 3,000 feet above the average elevation of the Laurentian plateau lying 25 miles northwest of Montreal. Thus the structural feature which constitutes the subject of this paper may be ignored without invalidating the conclusion that the nearly horizontal sediments of the Montreal region must have reached far to the north of the present Archæan border. The recognition of a great subsidence fault at the southern border of the Archæan, however, makes the conception of a limited northern extent for the Palæozoic still more improbable. The total thickness of the Palæozoic of the Montreal district, if we take the minimum figures of Adams and Leroy for the beds below the Utica-Lorraine, is about 5,025 feet. If the Laurentian scarp is the result of late Palæozoic or Post-Palæozoic faulting the sea floor of the early Palæozoic was not interrupted by any inequality of grade near the present southern border of the Archæan. The old Pre-Cambrian land surface near Montreal must, therefore, have been depressed nearly a mile below sea-level in order to permit the accumulation of the 5,000 feet of Palæozoic. We must postulate as an accessory to this subsidence at Montreal a regional depression of the areas to the north which permitted the Ordovician sea to invade much if not all of the Archæan area north of the Ottawa and St. Lawrence rivers. The elevation of the land near the divide between the Hudson Bay and the Ottawa-St. Lawrence drainage systems does not greatly exceed that of much of the southern part of the Laurentian plateau. East of Abitibi lake the highest

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[1] Bull. Geol. Soc. America, Vol. I, 1890, p. 172.

[2] A theory of continental structure applied to North America, Bull. Geol. Soc. America, Vol. 18, 1908, p. 394.

[3] Ann. Rept. Geol. Surv., Canada, new ser., vol. XIV, 1901, p. 270.

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[1] Idem, sheet No. 874, 1905.

The first number of the Museum Bulletin was entitled, *Victoria Memorial Museum Bulletin, Number 1.*

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8. Revision of the species which have been referred to the genus Bathyurus (preliminary paper); by P. E. Raymond.
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